AN2244
Application note

EEPROM emulation with ST10F27x embedded Flash using the ST10F27x Flash library

Introduction

The ST10F27x MCUs provide 0.18µm embedded true Flash technology.

This Flash technology has been designed to store software program instructions and is not adapted to dynamic data storage because it can only be erased by sector.

Typically, when the code is programmed, some portions of the Flash remain free. This unused space can be used as virtual EEPROM, thus avoiding the additional cost and complexity incurred by using an external serial EEPROM.

This application note shows a method of performing EEPROM emulation. It provides software routines to overcome the Flash limitations in terms of read/write access and number of cycles.

This document is divided into the following sections:

- Overview of ST10F27x Embedded Flash
- The ST10F27x Flash library provided by STMicroelectronics
- Application example: EEPROM Emulation. This application example helps the user to become familiar with the ST10F27x Flash library, given that it uses the main important Flash library functions of programming, erasing and verifying.

The application source files are provided within an associated downloadable package. This file must be unpacked into a directory before use.

The EEPROM emulation driver was compiled using the two tool chains, Tasking and Keil, and it can be ported easily to any other ST10 tool chain.

For more information, please refer to the ST10F27x related documentation.

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1 ST10F27x embedded Flash overview

The ST10F27x provides an on-chip high-speed single voltage Flash memory.

The write operations of the ST10F27x Flash banks are managed by an embedded Flash Program/Erase Controller.

The following table summarizes the main ST10F27x Embedded Flash characteristics:

	ST10F271	ST10F272	ST10F273	ST10F275	ST10F276
Flash Size (KBytes)	128	256	512	832	832
Flash Organization Banks / Sectors	1 /6	1 / 8	2 / 12	4 /17	4 /17
Programming voltage	5 Volts				
Programming method	Write/Erase Controller				
Program/Erase cycles	100 Kcycles, 20 years data retention				

Depending on the ST10 derivative, the Flash memory will be composed either of 1 module (IFLASH) or of 2 modules (IFLASH and XFLASH). Each module is divided into several banks, themselves sub-divided into sectors.

The ST10F276 and ST10F275 embedded Flash is composed of two modules.

The ST10F271, ST10F272 and ST10F273 embedded Flash is composed of one module.

On the IFLASH, the internal data bus is 32 bits wide (I-BUS).

The XFLASH module is mapped on the XBUS and the data bus is 16 bits wide (X-BUS).

The smallest erasable part of Flash is a sector.

2 The ST10F27x Flash library

The Flash programming library is a set of optimized C routines and contains everything needed to program the embedded Flash of ST10 devices in 0.18µ technology, i.e the ST10F27x family devices.

The Flash library contains the following source files:

- *flash.c*, containing the functions' code
- *flash.h*, containing the functions' prototypes
- *F27x_flash.h*, containing the definitions of the Flash registers and sectors' size for the ST10F27x devices Flash

To use the functions provided by the Flash library, these files must be added to the project. The CPU frequency must be set in *F27x_flash.h* library file:

#define Fcpu_MHz ((unsigned int) 40)

In order to be able to use the ST10F27x Flash library, the MCU(ST10F27x derivative) and the toolchain (Tasking or Keil) must be defined and start up configurations must be properly set up.

For more details about the ST10F27x Flash library and how to use it, please refer to the *"Flash programming for ST10 devices in 0.18um technology"* application note.

3 Application example: EEPROM emulation using ST10F27x Flash library

3.1 Purpose

The purpose of this example is to show how a portion of the ST10F27x embedded Flash can be used to replace a serial EEPROM to store and update non volatile data in order to save the cost of an external EEPROM.

3.2 Principle

The implementation shown in this application note requires that a minimum of two Flash sectors of identical size are allocated to non volatile data storage. In this example, the sector 1 and sector 2, 8 kbytes each, of the Flash bank 0 are used.

Those sectors are write accessed in 32-bit.

A header field occupying the first 32-bit word of each sector represents the sector's status.

In order to use Flash to store several non volatile variables, we need to divide the two sectors identically into several parts, one per variable.

For each variable, the size of the memory space is allocated according to its update frequency. The first 32-bit value of each variable is stored at the base address of its allocated memory space. When updated, the new value is stored at the next available address: base address + 4, base address + 8 and so on until no room remains from its allocated memory.

Example:

In the sector 1, we assume 3 variables: A, B and C will be stored and updated.

The first variable A value is stored at t_0 and variable A(t) is updated every t_A

The second variable B value is stored at t_1 and variable B(t) is updated every t_B

The third variable C value is stored at t_2 and variable C(t) is updated every t_C

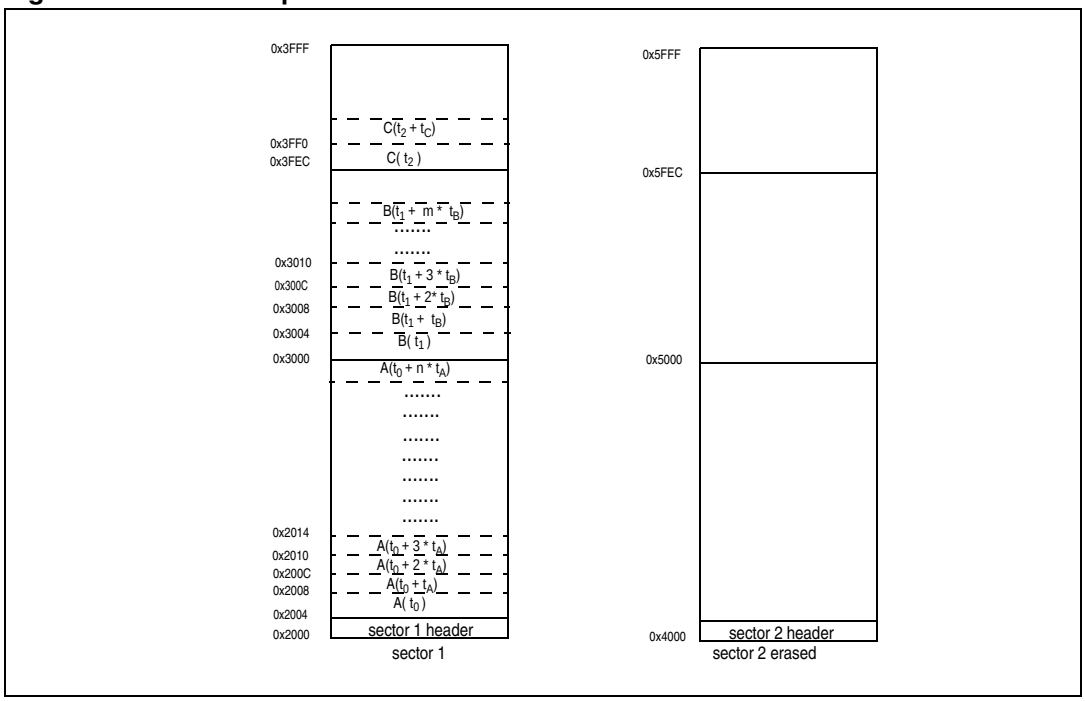
In a typical application, the majority of non volatile data is updated infrequently and a few is updated more frequently.

Let's consider $t_A < t_B < t_C$, this means that A is updated more than B which is updated more than C so more memory space should be allocated to A and B than C.

In this application, sector 1 is divided as follows:

- 0x2000-0x2FFF memory space will be allocated to variable A
- 0x3000-0x3FEB memory space will be allocated to variable B
- 0x3FEC-0x3FFF memory space will be allocated to variable C

Figure 1. Variable updates in sector 1



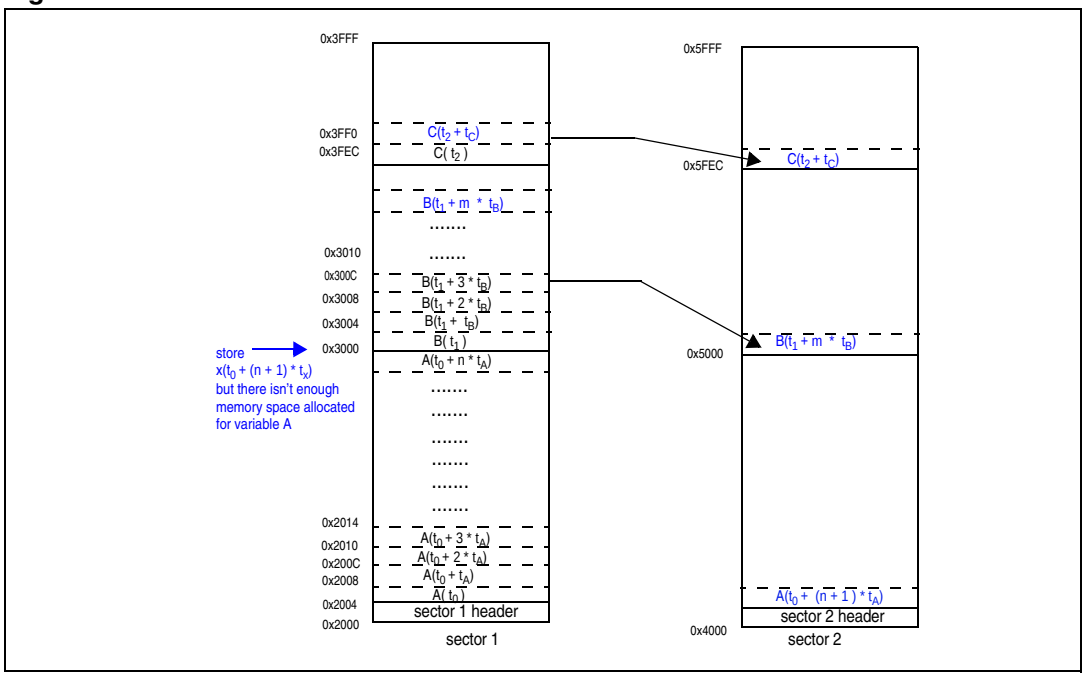
In sector 1, variables are stored until there is insufficient memory space to allocate to one of these variables (case of variable A in the example).

Assume that the variable A should be updated at the time $t_0 + (n+1) * t_A$ with $A(t_0 + (n+1) * t_A)$. Addresses from 0x2004 to 0x2FFC are all full, the next value is then stored in the base address of the space allocated to the variable A in the sector 2.

The latest stored value of every other variable (B and C) is transferred from its last location in sector 1 to the base address of its allocated space in sector 2.

This is illustrated in the *Figure 2*.

Figure 2. Variable transfer when sector 1 is full



After the transfer of all variables is complete, sector 1 is erased.

Variables are then stored and updated in sector 2 in the same way described for sector 1.

When there is not enough memory space left for one of these variables in sector 2, we switch back to sector 1 (now empty) in the same way and so on.

3.3 ST10F27x embedded Flash vs. EEPROM: program/erase cycles

One program/erase cycle is composed of one or several write accesses and one sector erase operation.

When EEPROM technology is used, each byte can be programmed and erased a finite number of times, typically in the range of 10,000 to 100,000.

However, when Flash is used, the minimum erase size is a sector and the number of Program/Erase cycles applied to a sector is the number of erase cycles. The ST10F27x electrical characteristics guarantee 100,000 Program/Erase cycles per sector.

In our example, two 8 kbyte sectors are used and programming is done with 32-bit words.

If we consider that the memory space allocated to variable A is always filled up before spaces allocated to variables B and C, the expected number of erase cycles is driven by variable A. As 4092 bytes are allocated to A, it can be updated 1023 times before switching and erasing sectors. Two sectors are used that can be erased 100,000 times so the total number of cycles we can expect for A is: 1023 x 2 x 100,000 = 204,600,000 cycles.

The number of cycles (common to all variables) is the number of cycles taken for the 1st variable to fill all of its allocated memory space (variable A in our example).

3.4 EEPROM software description

This section describes the software implemented for EEPROM emulation using the ST10F27x Flash library provided by STMicroelectronics.

This example uses the 3 variables A, B and C already defined.

The project contains 3 source files in addition to the three library source files:

- **eeprom.c**: containing C code for the following project routines

```
EepromFormat( )
WriteVariable( )
ReadVariable( )
FindValidSector( )
WriteVerifyVariableFull( )
EepromSectorTransfer( )
FlashRead( )
```

- **eeprom.h**: containing the routines' prototypes and some declarations.
- **main.c**: This application program is an example that uses the routines described in *eeprom.c* in order to write and read from the eeprom.

3.4.1 Header field

The header field occupies each sector base address and gives the sector's status information. Each sector has four possible states:

- **ERASED**: This sector is empty.
- **RECEIVE_DATA**: This sector is receiving data from the full one.
- **VALID_SECTOR**: This sector contains valid data and this state will not change until valid data are completely transferred to the erased sector.
- **TRANSFER_COMPLETE**: Transfer of data to the other sector is finished and this sector is no longer in use. The system can then erase this sector to prepare it for future data.

The *Figure 3* shows how to switch from one state to another for both sectors.

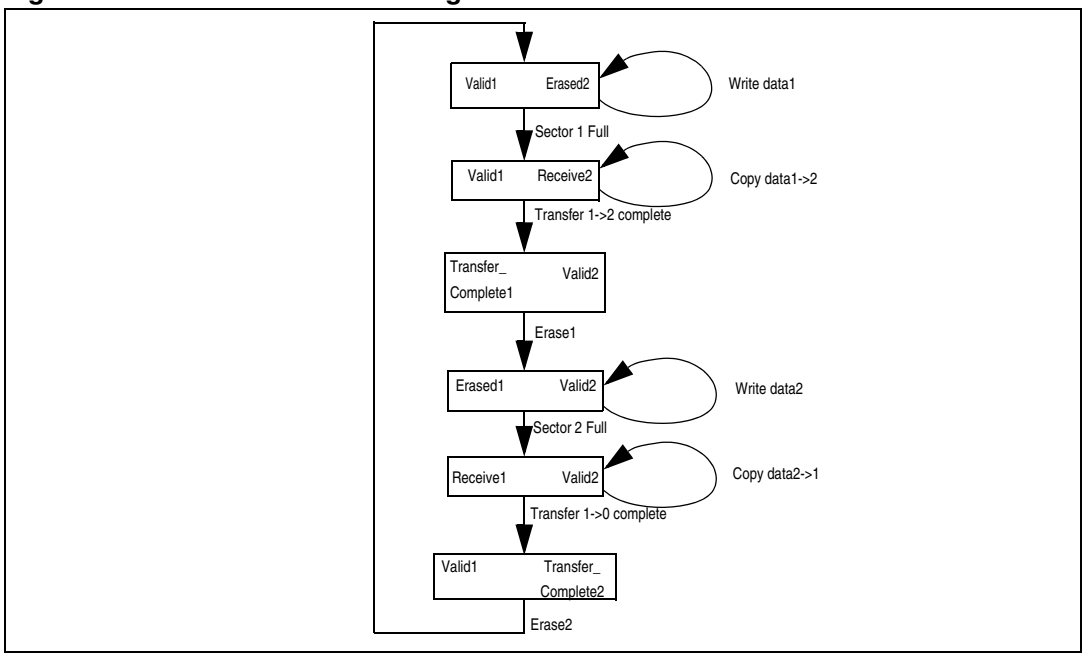
3.4.2 Variables array

Every variable is defined by its start address in its allocated memory space.

An array of variables is declared and located in the user application as described in *Section 3.4.4*

Its size must be defined in the *eeprom.h* file.

Figure 3. Header status switching between sectors 1 and 2



3.4.3 Project routines

EepromFormat( ) routine

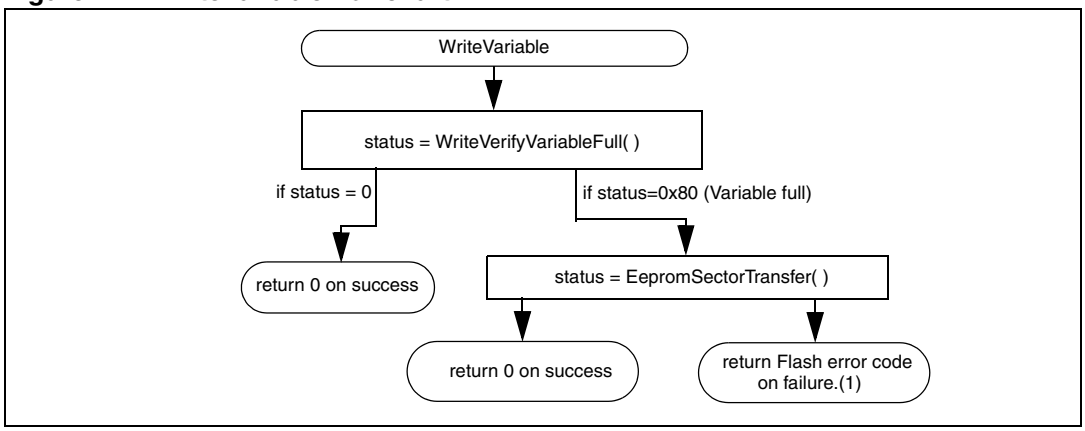
This function erases sector 1 and sector 2, and writes a VALID_SECTOR header to sector 1.

WriteVariable( ) routine

This function is called by the user application. It uses **WriteVerifyVariableFull( )** and **EepromSectorTransfer( )** routines described later.

See below the procedure of updating a variable entry in the eeprom.

Figure 4. WriteVariable flowchart



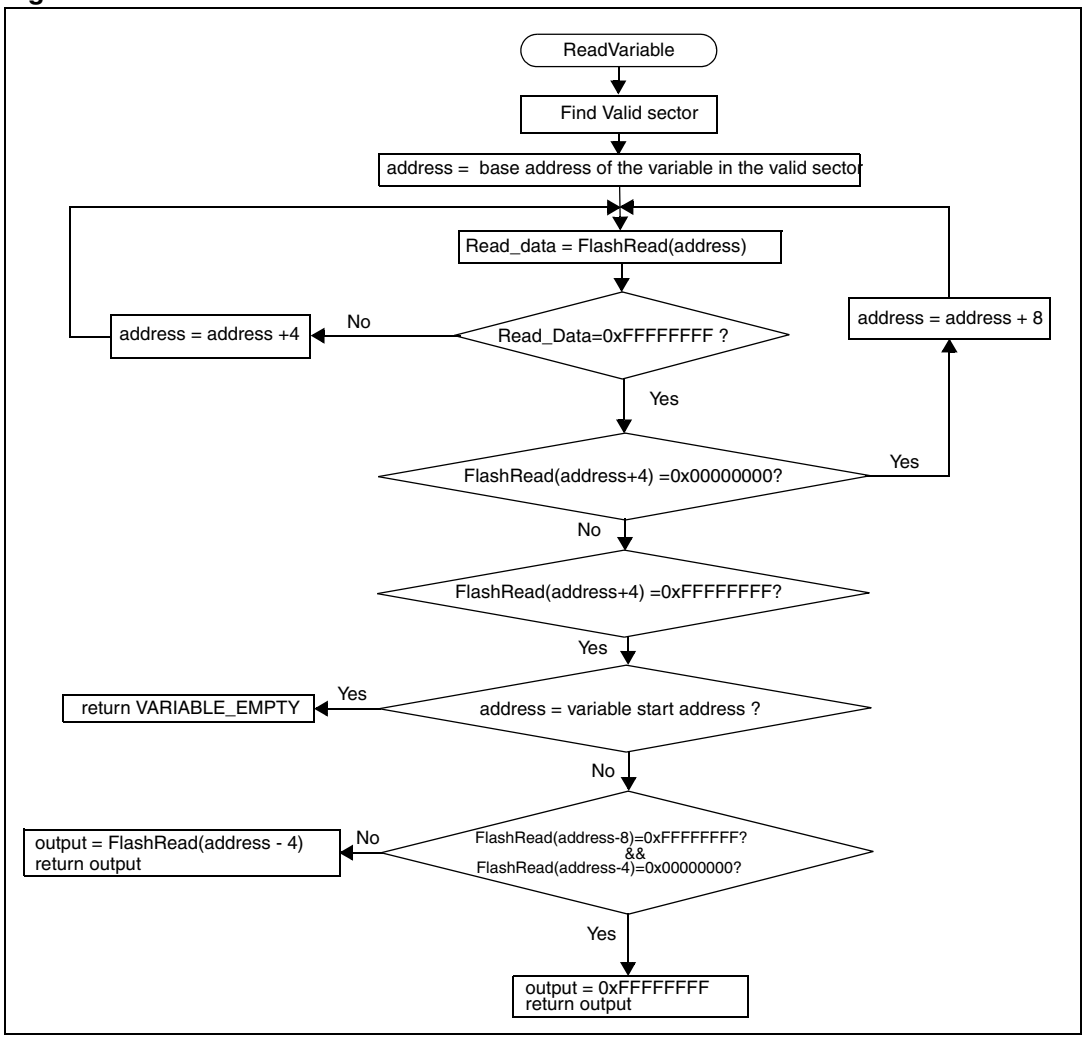
Note: 1 For more informations about Flash error codes, please refer to the "Flash programming for ST10 devices in 0.18µ technology" application note.

ReadVariable( ) routine

This function reads variable data. Only last update is read. The function enters in a loop in which it reads the variable entries until the last one is found. Finally, the data is returned.

See below for the procedure of reading the last variable entry in the eeprom.

Figure 5. ReadVariable flowchart



WriteVerifyVariableFull( ) routine

If a write should occur, the write process must either update a variable, or create the first instance of a variable. The routine has as parameters:

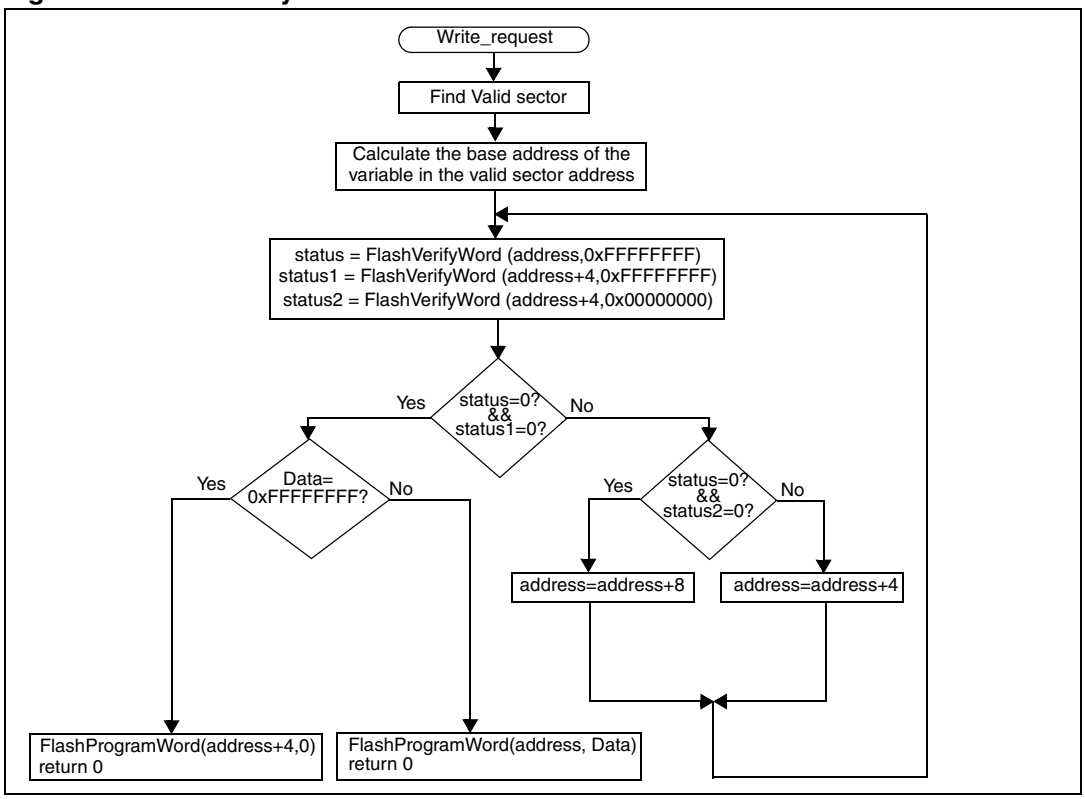
- variable index (0 for A, 1 for B or 2 for C)
- all variables Array
- 32-bit data to be written

If the data to be written is equal to 0xFFFFFFFF, we look for the last data equal to 0xFFFFFFFF and we write 0x00000000 in next location to indicate that 0xFFFFFFFF is a data and not a blank location.

If the data to be written is different from 0xFFFFFFFF, we look for the last data equal to 0xFFFFFFFh (the following location should not contain 0x00000000) and the data is written at this location.

The following diagram summarizes the write operation and treats the cases where written data is equal to or different from 0xFFFFFFFF. This routine will return 0 on success, VARIABLE_FULL if there isn't enough memory for a variable update, or a Flash error code indicating an operation failure (erase or program).

Figure 6. WriteVerifyVariableFull routine flowchart

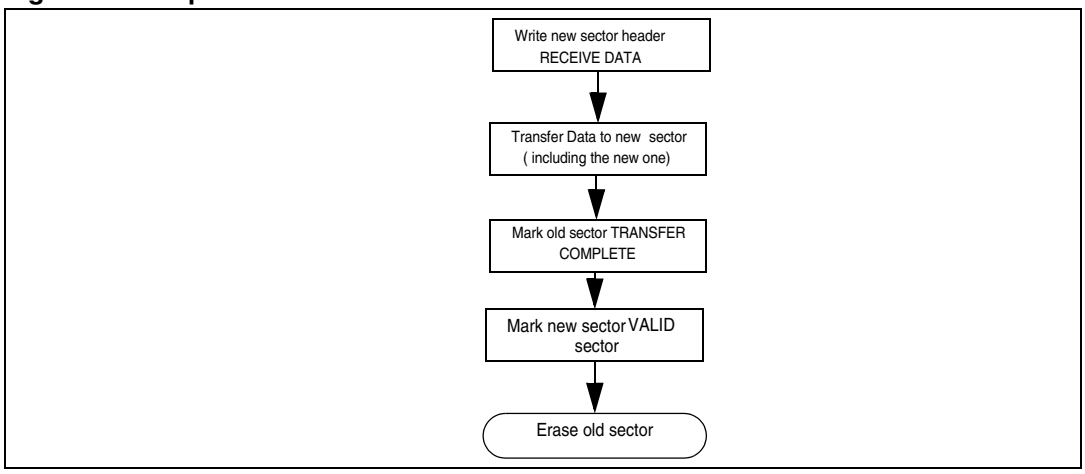


EepromSectorTransfer( ) routine

This routine transfers the most recent data (Last variable updates) plus the new one from a full sector to an empty one. At the beginning, it determines the active sector which is the sector that we want to transfer from. The new sector header field is defined and written (new sector status is RECEIVE_DATA given that it is in the process of receiving data). When, the data transfer is complete, the new sector header is marked VALID_SECTOR and the old one TRANSFER_COMPLETE. At the end, the old sector is erased.

The transfer process is shown in the following figure:

Figure 7. EepromSectorTransfer flowchart

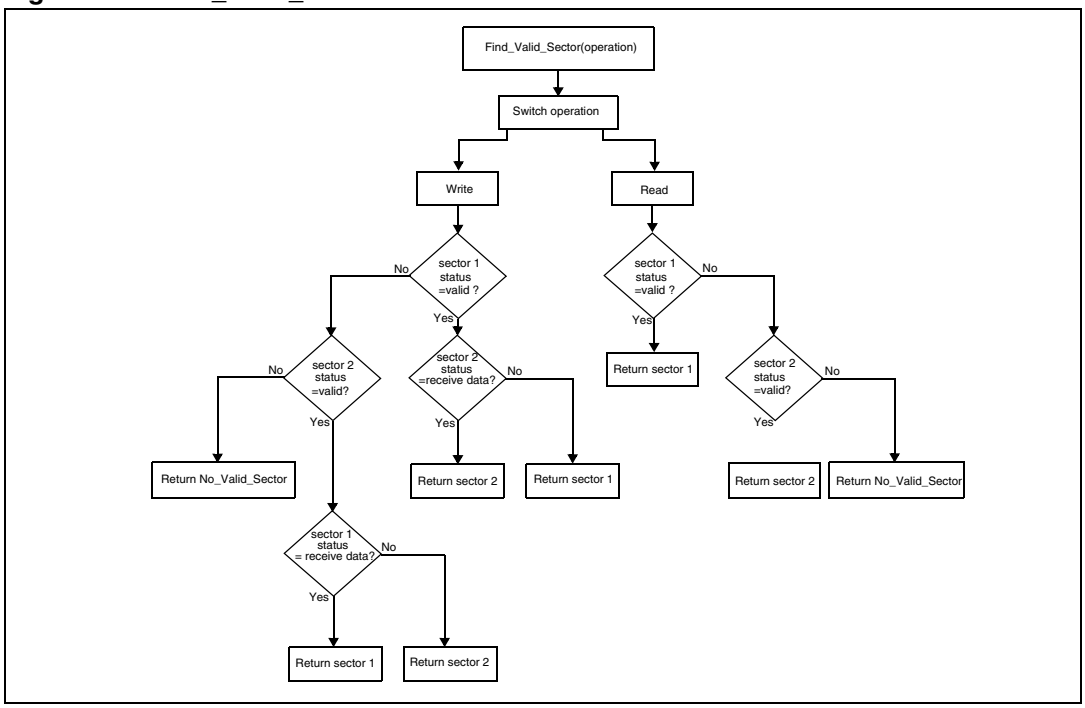


FindValidSector( ) routine

This function reads both sector headers and returns the sector number which contains valid data. It has as parameter a byte indicating that we are looking for a valid sector for write or read operation(READ_FROM_VALID_SECTOR or WRITE_IN_VALID_SECTOR).

The following diagram describes this routine principle.

Figure 8. Find_Valid_sector flowchart



FlashRead( ) routine

This routine allows 32-bit data to be read from a given Flash address.

Program/Erase functions

In this application, the following functions provided by the Flash library are used:

- FlashVerifyWord( )
- FlashProgramWord( )
- FlashSectorErase( )
- FlashWait( )

3.4.4 Using EEPROM routines in a main program

The number of variables needed must be defined in the *eeprom.h* file. For example,

```
#define max_varia  0x3
#define A 0x2004
#define B 0x3000
#define C 0x3FEC
//#define D ...
etc...
```

The application must declare the variables array:

```
u32 Tab[max_varia]   =
    {A,
     B,
     C
     //D,
     etc...
     };
```

To write in the eeprom, use the **WriteVariable( )** routine which returns "0" on success and the error code upon failure. Reading from the eeprom is performed by the **ReadVariable( )** routine.

3.4.5 Program execution

The internal Flash of some ST10F27x derivatives (ST10F276, ST10F275 and ST10F273) offers the ability to update one bank while code is executed from another bank. Therefore there is no need to transfer Flash operations (Program/Erase) to RAM. In this case, the emulation driver can be downloaded into a bank other than bank0.

The internal Flash of the remaining ST10F27x dervatives (ST10F271 and ST10F272) contains just one bank. Therefore, the Flash operations (Program/Erase) must be copied into and executed from RAM.

4 Software limitations

Data or sector headers corruption is possible in the case of power loss during variables update or sectors erase or transfer.

To detect this corruption and recover it, a routine EEPROM_INIT( ) must be written and called immediately after power on.

This routine is not implemented in this version of this application note. This section is limited to the description of its principle.

The routine must use the sector status to check integrity and to perform repair if necessary.

After power loss, the EEPROM_INIT( ) routine is used to check sector header status. There are 16 possible status combinations, half of which are invalid. The following table shows the actions that should be taken based on the sectors states upon power up.

Table 1. Status combinations and actions to be taken

Sector 1 / Sector 2	ERASED	RECEIVE_DATA	VALID_DATA	TRANSFER COMPLETE
ERASED	Invalid state: erase both sectors and format sector 1	Invalid state: erase both sectors and format sector 1	Use sector 1 as valid sector and erase sector 2	Invalid state: erase both sectors and format sector 1
RECEIVE_DATA	Invalid state: erase both sectors and format sector 1	Invalid state: erase both sectors and format sector 1	Use sector 1 as valid sector and erase sector 2 and transfer data from 1 to 2	Use sector 2 as valid sector and erase sector 1
VALID_DATA	Use sector 2 as valid sector and erase sector 1	Use sector 2 as valid sector and erase sector 1 and transfer data from 2 to 1	Invalid state: erase both sectors and format sector 1	Use sector 2 as valid sector and erase sector 1
TRANSFER COMPLETE	Invalid state: erase both sectors and format sector 1	Use sector 1 as valid sector and erase sector 2	Use sector 1 as valid sector and erase sector 2	Invalid state: erase both sectors and format sector 1

5 References

[1] ST10F276 datasheet

[2] "Flash programming library for ST10 devices in 0.18 µm technology"

6 Revision history

Table 2. Document revision history

Date	Revision	Changes
17-Jan-2007	1	Initial release.

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